

Safety Effects of Street Illuminance at Urban Signalized Intersections in Florida

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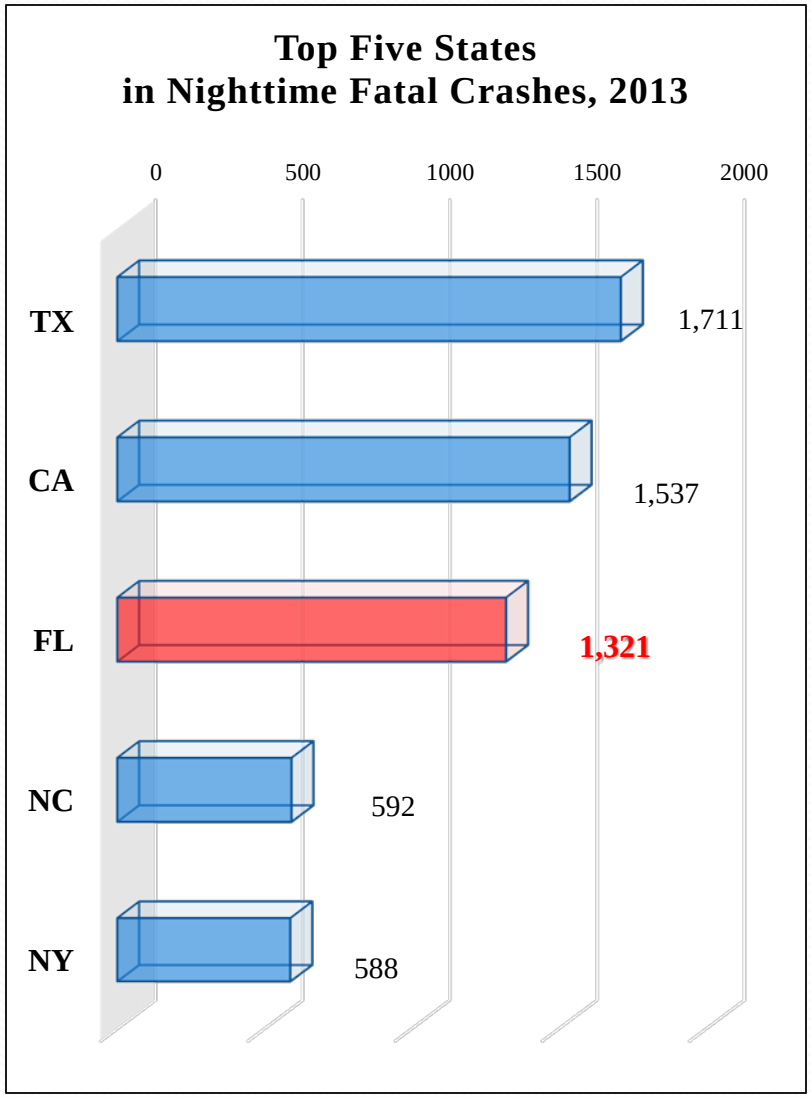
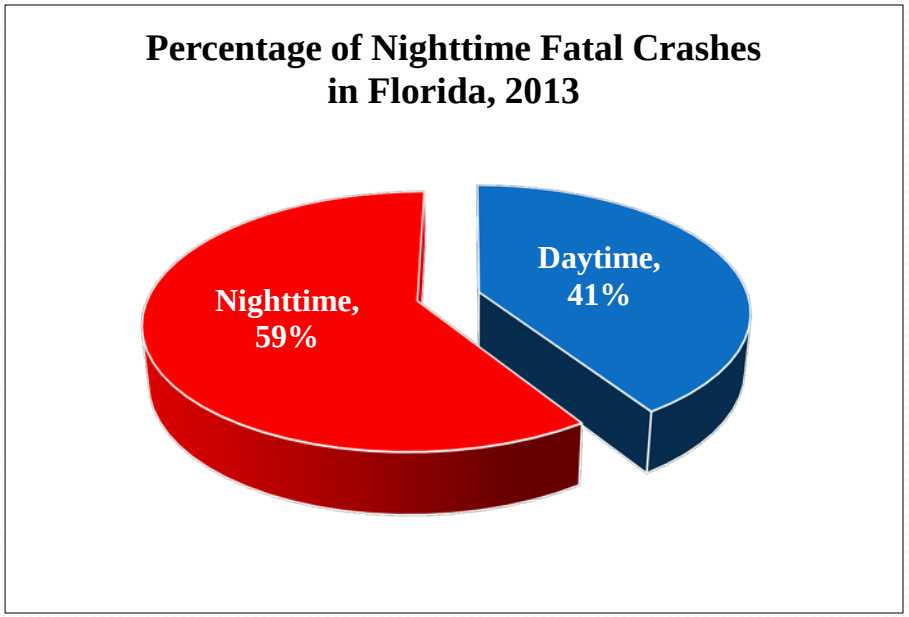
Outline

- Background
- Data Collection
- Methodology
- Results and Findings
- Conclusions

Nighttime Fatal Crash Facts





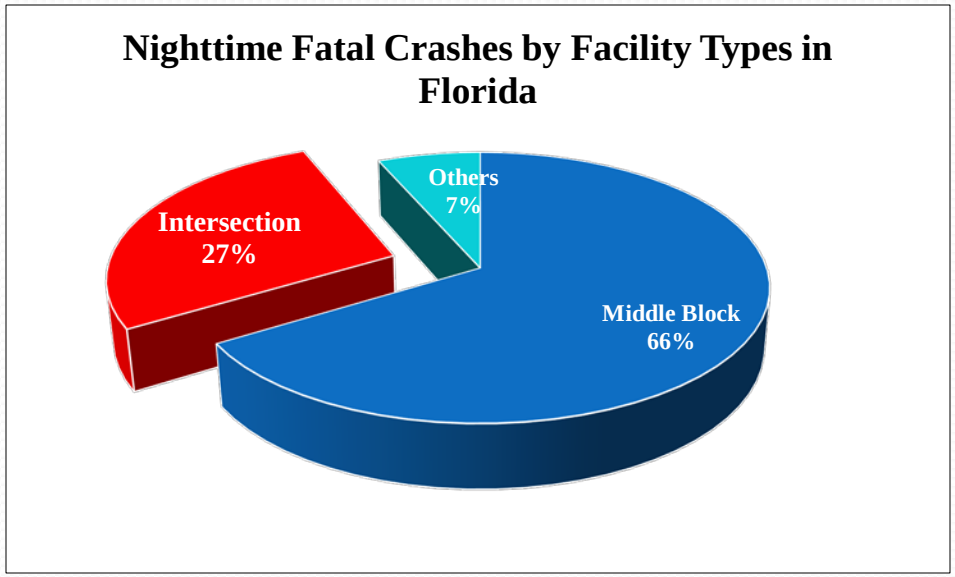
Only **21-23%** of the vehicle miles traveled (VMT) occurred at night. (*Monsere and Fischer, 2008*)

Nighttime includes Dark, Dark w. Light Dusk, and Dawn

Source: NHTSA FARS 2013

Nighttime Crash Facts at Intersections

- Planed points of conflict in any roadway system
  - Vehicle-Vehicle
  - Vehicle-Pedestrian
- High traffic and pedestrian volume
- Receive more attention in nighttime safety



Nighttime includes Dark, Dark w. Light Dusk, and Dawn

Source: NHTSA FARS 2013

Street Lighting

- Additional visibility to help drivers complete the driving task.
- A safety countermeasure to reduce nighttime crashes at signalized intersections.
  - "*AASHTO Strategic Highway Safety Plan Implementation Guide*"
- FDOT Roadway Lighting Requirements

Road Classification	Illumination Level Average Initial Horizontal Foot Candle (HFC)	Uniformity Ratios	
		Avg/ Min	Max/Min
Interstates, Expressways, Freeways, and Major Arterials	1.5	4:1 or less	10:1 or less
All other Roadways	1.0	4:1 or less	10:1 or less
Pedestrian Ways and Bicycle Lanes	2.5	4:1 or less	10:1 or less

Past Studies

- Safety effects of installation of street lighting
- Safety effects of quantified horizontal illuminance at intersections
  - Edwards. 2015 — Minnesota
    - 1-lux increase reduced nighttime crash by 9%, 20%, 95% for all, lighted, and unlighted intersections, respectively
  - Bhagavathula et al. 2015 — Virginia
    - 1-lux increase reduced night-to-day ratio by 7%, 9%, and 21% for all, lighted, and unlighted intersections, respectively

Research Objectives

- To address the influence of the horizontal illuminance on nighttime crash frequency at urban signalized intersections;
- To quantify the influence of the horizontal illuminance on night-to-day crash ratio; and
- To address the influence of the horizontal illuminance on nighttime crash injury severity at urban signalized intersections.

Advanced Lighting Measurement System

Current version: 2.1

Up to 6 lighting meter inputs

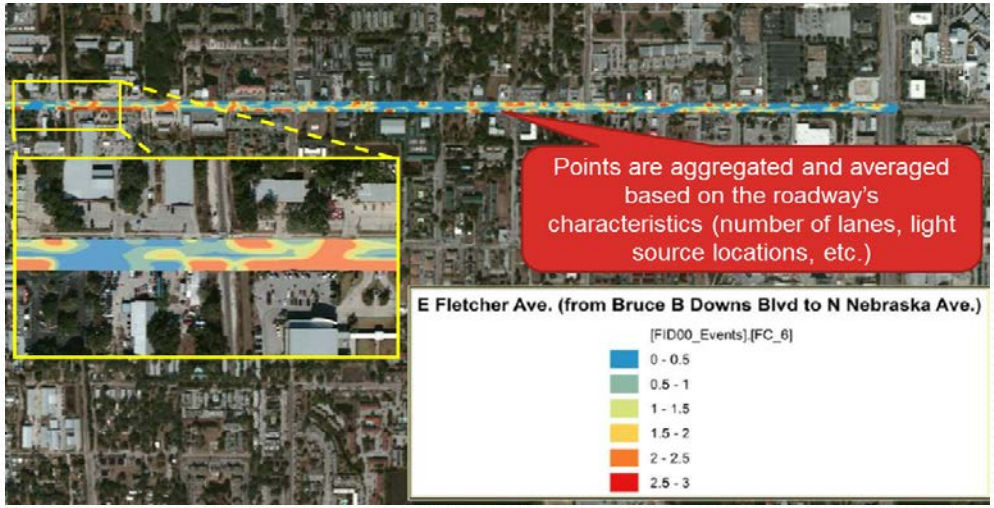
Horizontal illumination

High accuracy

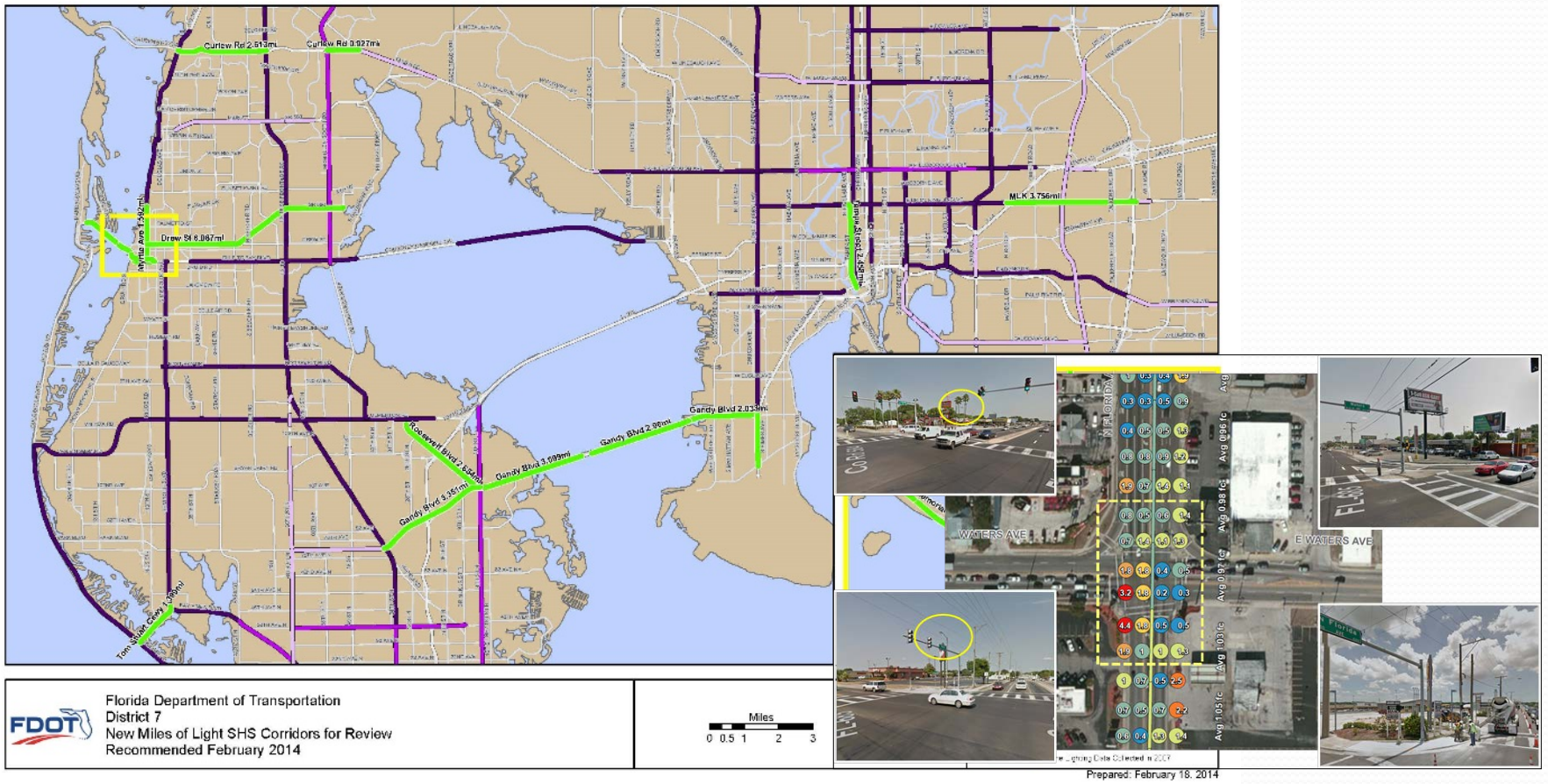
Resolution: 2 points per 10 feet

Speed: = 30 mph

Special event logger



Lighting Data Collection



- Completed data collection for **300+ centerline miles** in Tampa Bay
- 2012 - 2014

Site Selection

- A total of 91 signalized intersections with street lights were selected
  - Located in urban area
  - High Pressure Sodium (HPS)
  - No upgrade in past four years

- A circular buffer with a 100-feet radius

Data Collection

- Illuminance Data
  - Average horizontal illuminace (foot-candle, fc)
  - 2012 — 2014
- Crash Data
  - Florida Crash Analysis Reporting (CAR) system
  - 2010 – 2013
  - Daytime (daylight) + Nighttime (dark)
- Others
  - Geometry – Google Maps, Florida RCI
  - Traffic – Florida Traffic Information DVD

Data Description for Crash Frequency Modeling

Count Variables	Min.	Max.	Mean	Std. Dev.
Daytime crash frequency (2010-2013)	0	102	36.20	24.21
Nighttime crash frequency (2010-2013)	0	46	15.50	10.99
Continuous Variables	**Min.**	**Max.**	**Mean**	**Std. Dev.**
Log(AADT) on major road	8.55	11.12	10.30	0.49
Log(AADT) on minor road	7.17	10.94	9.43	0.95
Categorical Variables	**Code**		**Freq.**	**Percent**
Intersection Type	0 – 3-leg intersection		10	10.99
	1 – 4-leg intersection		81	89.01
Lighting Level	1 – average illuminance < 0.2 fc		8	8.79
	2 – 0.2 ≤ average illuminance < 1.1 fc		73	89.01
	3 – average illuminance ≥ 1.1 fc		10	10.99
Observations	91			

Data Description for Injury Severity Modeling

Categorical Variables	Code	Freq.	Percent
Injury Severity	0 – slight injury/property damage only	1,109	89.87
	1 - death or serious injury	125	10.13
Lighting Level	0 – illuminance < 0.9 fc	804	65.15
	1 – illuminance ≥ 0.9 fc	430	34.85
Crash Type	1 – rear-end	512	41.49
	2 – head-on	46	3.73
	3 – angle	412	33.39
	4 – sideswipe	45	3.65
	5 – pedestrian/bicycle	60	4.86
	6 – others	159	12.88
Observations	1,234		

Modeling Methods

- Negative binomial (NB) model
  - Expected nighttime crash frequency (N)
  - Expected daytime crash frequency (D)
  - By lighting level categories (low, medium, high)

- Night-to-day crash ratio change

$$\frac{(N_a/D_a) - (N_b/D_b)}{(N_b/D_b)} \times 100\%$$

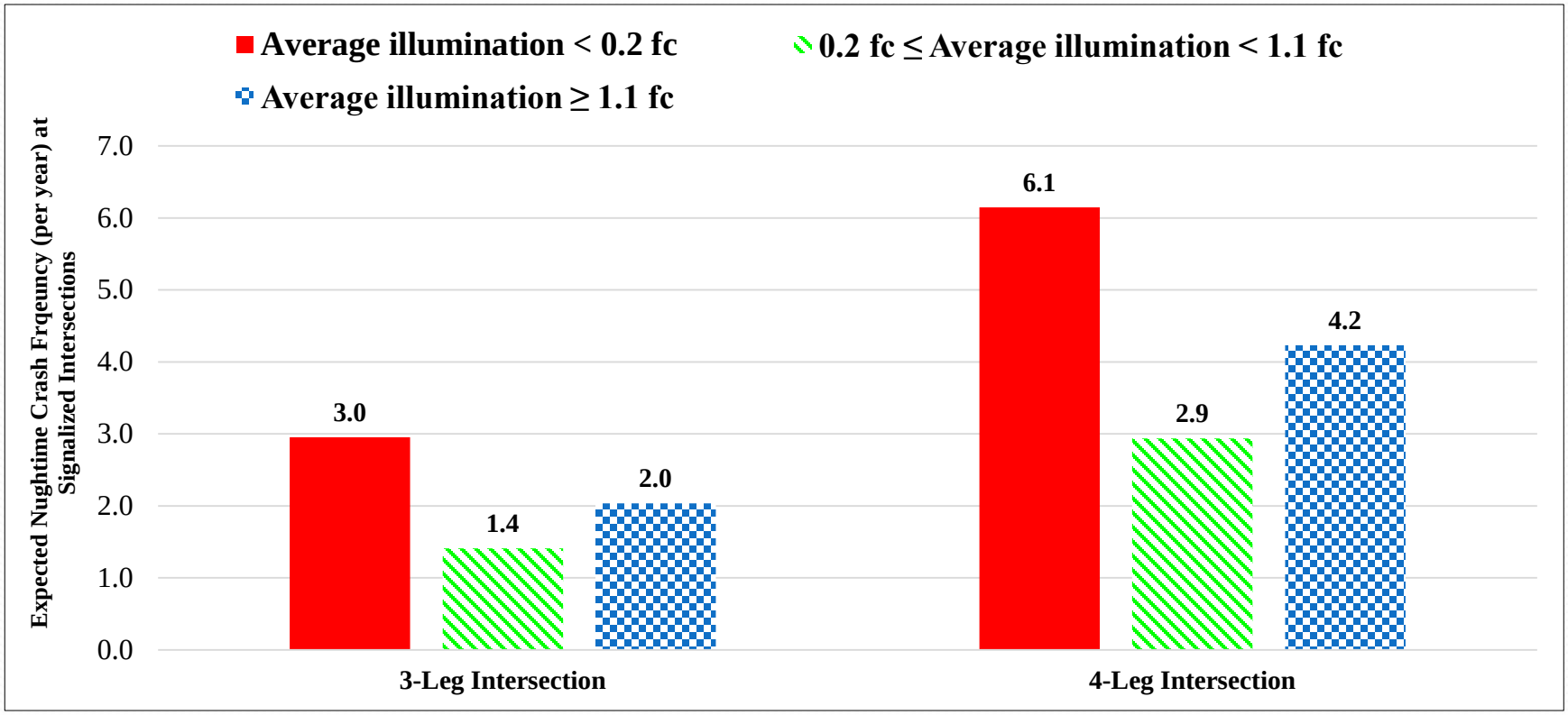
- Binary probit (BP) model
  - Probability of fatal and severe injury

Fitted NB Model

Variable	NB Model I		NB Model II (with a yearly indicator)	
	Nighttime	Daytime	Nighttime	Daytime
	Coeff.	Coeff.	Coeff.	Coeff.
Log AADT on major road	0.468*	0.403*	0.417*	0.372*
Log AADT on minor road	0.414*	0.347*	0.387*	0.310*
Average illumination < 0.2 fc	0.739*	0.083	0.729*	0.072
0.2 fc ≤ Average illumination < 1.1 fc	*Baseline*			
Average illumination ≥ 1.1 fc	0.365**	0.218	0.312*	0.18
4-leg intersection	0.7330*	0.432**	0.803*	0.521*
2010	-	-	*Baseline*	
2011 (1=year 2011; 0=otherwise)	-	-	-0.289*	-0.346*
2012 (1=year 2012; 0=otherwise)	-	-	-0.146	-0.239*
2013 (1=year 2013; 0=otherwise)	-	-	-0.227*	-0.098
Constant	-6.999*	-4.336*	-7.453*	-4.927*
Over-dispersion parameter (α)	0.296	0.310	0.258	0.329
Model Statistics				
Number of observations	91	91	364	364
DF	7	7	10	10
Log Likelihood	-304.080	-389.970	-783.619	-1,099.307
Pseudo R^2	0.069	0.045	0.075	0.052

* Statistically significant at 95% confidence level.
** Statistically significant at 90% confidence level.

Expected Nighttime Crash Frequency



- Increase Illuminance from **< 0.2 fc** to **0.2 fc – 1.1 fc** will reduce nighttime crash number by
  - 53% (1.6 per year) at 3-leg intersections
  - 52% (3.1 per year) at 4-leg intersections

Expected Night-to-day Crash Ratio

- Relevant nighttime crash frequency compared to daytime crash frequency

- Compared to the low illuminance (< 0.2 fc), the medium illuminance (0.2 – 1.1 fc) will reduce N-D ratio by **48%**

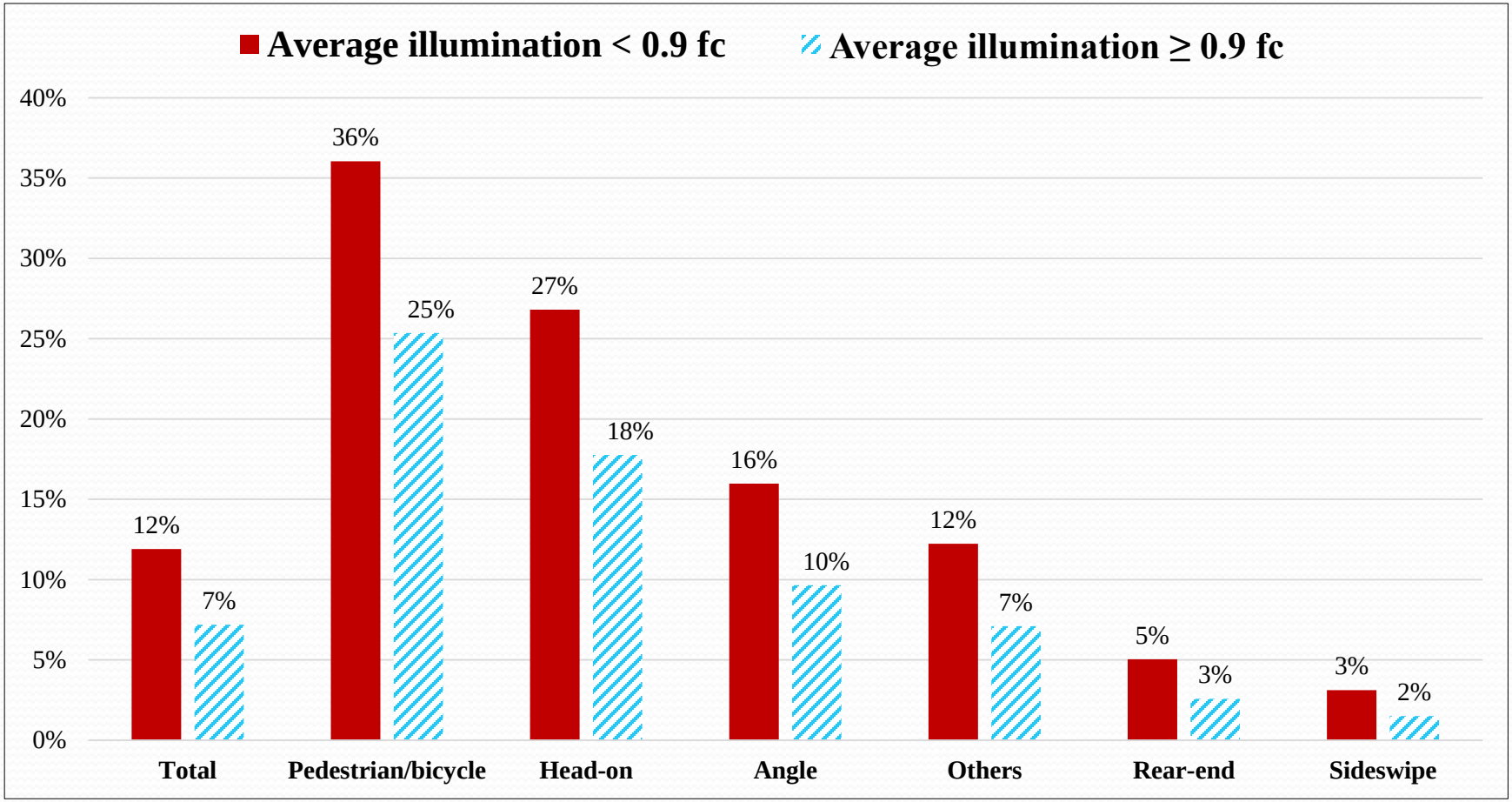
$$\frac{\frac{\exp(0.739 \times 0 + 0.365 \times 0)}{\exp(0.083 \times 0 + 0.218 \times 0)} - \frac{\exp(0.739 \times 1 + 0.365 \times 0)}{\exp(0.083 \times 1 + 0.218 \times 0)}}{\frac{\exp(0.739 \times 1 + 0.365 \times 0)}{\exp(0.083 \times 1 + 0.218 \times 0)}} \times 100\% = -48\%$$

- Compared to the medium illuminance (0.2 – 1.1 fc), the high illuminance (≥ 1.1 fc) will increase N-D ratio by **15.8%**

Fitted Probit Model

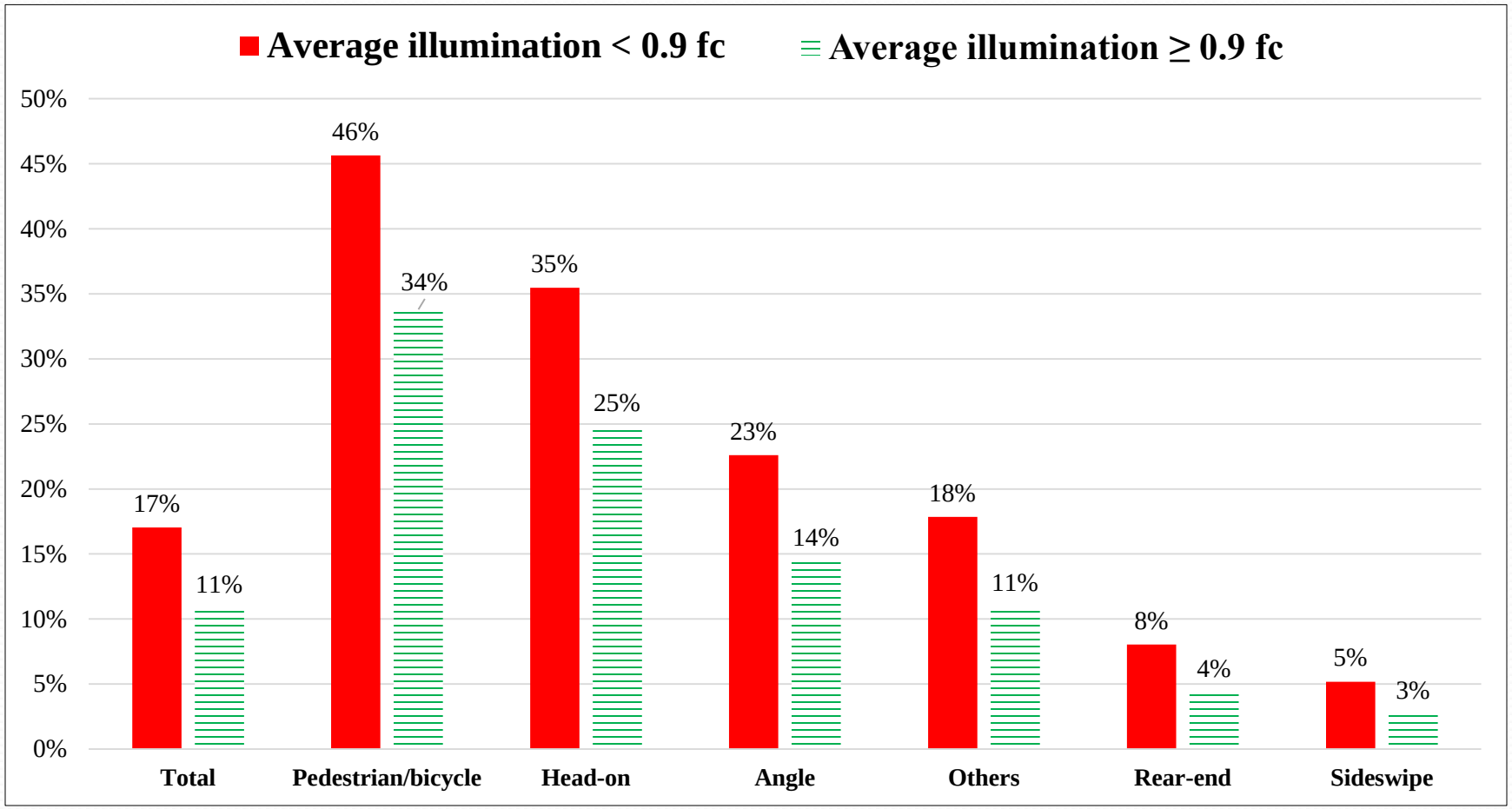
Variable		Coef.	Std. Err.	z	P>z	[95% CI]	
Average illuminance	≥ 0.9 fc	-0.308	0.125	-2.460	0.014	-0.553	-0.063
Crash Type	Rear-end			*Baseline*			
	Head-on	1.030	0.244	4.230	0.000	0.553	1.507
	Angle	0.650	0.142	4.580	0.000	0.372	0.929
	Sideswipe	-0.225	0.465	-0.480	0.628	-1.135	0.686
	Pedestrian/bicycle	1.293	0.217	5.960	0.000	0.868	1.718
	Others	0.482	0.185	2.610	0.009	0.119	0.844
Alcohol/Drug	Involved	0.304	0.140	2.160	0.031	0.029	0.579
Constant		-1.706	0.122	-13.980	0.000	-1.945	-1.467

Predicted Probability of Fatality and Severe Injury by Crash Types



Predicted Probability of Fatality and Severe Injury by Crash Types

Alcohol/Drug Involvement



Conclusions

- Street lighting is an effective countermeasure to improve safety at signalized intersections, especially for pedestrians and bicyclists
- To reduce crash frequency, illuminance should be 0.2 - 1.1 fc
- To reduce crash severity, illuminance should be ≥ 0.9 fc
- Maintain the average illuminance at signalized intersections **0.9 fc or higher**